

What is claimed is:

1. An apparatus, comprising:
 - a planar substrate; and
 - an array of substantially transparent spherical micro-lenses on the substrate, the micro-lenses forming a pattern, the pattern having an internal two-dimensional lattice symmetry on the planar substrate; and
 - 5 wherein each micro-lens comprises one of a convex bulge in a surface of the planar substrate and concave depression in a surface of the planar substrate; and
 - wherein the micro-lenses and substrate comprise hydrogel that swells and contracts in a manner responsive to an environmental condition.
- 10 2. The apparatus of claim 1, wherein each micro-lens has one spherical surface and one flat surface, the flat surface being on an opposite side of the substrate as the spherical surface.
- 15 3. The apparatus of claim 1, further comprising:
 - a second planar substrate that is substantially transparent; and
 - wherein the array is constrained to rest on the second substrate in a manner than enables the array to swell and contract.
- 20 4. The apparatus of claim 1, wherein a center-to-center spacing between the micro-lenses of the array is less than about 500 microns.
- 25 5. The apparatus of claim 6, further comprising:
 - a spatially segmented light intensity detector positioned to intercept light spots produced by the micro-lenses; and
 - a data processor configured to receive intensity and position data from the light intensity detector.
- 30 6. A method for fabricating a micro-lens array; comprising:
 - exposing a layer of photosensitive starting medium to one or more interference patterns of multiple light beams to produce therein a concentration pattern of reaction

products that tracks a time-integrated light intensity produced by the one or more interference patterns in the layer;

curing and then washing the layer to produce a cross-linked master pattern with a surface-relief that tracks the concentration pattern of reaction products; and

5 forming from the master pattern a replica stamp whose surface-relief is a negative copy of the surface-relief of the master pattern and includes a regular two-dimensional array of lens-shaped structures.

7. The method of claim 6, further comprising:

10 pressing the surface-relief of the replica stamp into a layer of liquid precursor for a hydrogel; and

curing the layer to form a cross-linked hydrogel with a surface-relief that is a negative copy of the surface-relief of the replica stamp.

15 8. The method of claim 7, further comprising:

swelling the replica stamp by soaking the replica stamp in a solvent prior to performing the pressing.

9. The method of claim 7, further comprising:

20 removing the surface-relief of the replica stamp from the cured layer to produce a hydrogel micro-lens array.

10. The method of claim 9, wherein the micro-lens array has a regular 2D lattice symmetry.

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11. The method of claim 7, wherein the replica stamp comprises a cross-linked elastomer.

12. The method of claim 7, wherein the exposing comprises one of
30 exposing the layer to an interference pattern formed by three mutually coherent light beams and exposing the layer to two interference patterns formed by two mutually coherent light beams.

13. The method of claim 7, wherein the photosensitive starting medium is a homogeneous mixture that includes oligomers, solvent molecules, dye molecules, and photo-initiator complexes.

5 14. A method for fabricating a micro-lens array; comprising:
exposing a layer of photosensitive hydrogel starting medium to one or more
interference patterns of multiple light beams to stimulate a reaction that produces a
concentration pattern of reaction products in the layer, the concentration pattern
tracking a time-integrated light intensity produced by the one or more interference
10 patterns of multiple light beams in the layer; and
curing the film to produce a cross-linking pattern that tracks the concentration
pattern of reaction products; and
then, washing the cured film to remove uncross-linked oligomers and produce
a layer of hydrogel comprising an array of spherical micro-lenses.

15 15. The method of claim 14, wherein each micro-lens comprises one of a
convex bulge in a planar surface of the layer of hydrogel and concave depression in a
planar surface of the layer of hydrogel; and
wherein the array has an internal two-dimensional lattice symmetry.

20 16. The method of claim 14, wherein the exposing comprises one of
exposing the layer to a pattern formed by interfering three mutually coherent light
beams and exposing the layer to two patterns formed by interfering two mutually
coherent light beams.

25 17. The method of claim 14, wherein the array of micro-lenses forms a
pattern that tracks the pattern of reaction products.

18. The method of claim 14, wherein the photosensitive hydrogel starting
30 medium is a homogeneous mixture that includes hydrogel oligomers, solvent
molecules, cross-linkers, dye molecules, and photo-initiator complexes.